BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: The Surveyor III Mission and Its Relation to Apollo - Case 340

DATE: June 19, 1967

FROM: F. N. Schmidt

ABSTRACT

This memorandum discusses some of the preliminary results of the Surveyor III mission and their relationship to an Apollo lunar landing. The confidence in the integrity of the lunar surface at the Surveyor I and III sites to support a LM and walking astronauts has greatly increased.

However, complete confidence does not yet exist such that all problems associated with the surface interaction of the LM descent engine exhaust can be predicted. The successful static firing of the vernier engines on future Surveyor missions must therefore, remain a primary objective.

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(NASA-CR-154361) THE SURVEYOR 3 MISSION AND ITS RELATION TO APOLLO (Bellcomm, Inc.) 5 p

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MEMORANDUM FOR FILE

INTRODUCTION

The Surveyor III spacecraft landed on the eastern slope of a shallow crater approximately 200 m in diameter and 17 m deep, coming to rest on a 14° slope. The landing point is located in a candidate Apollo site in southeast Oceanus Procellarum having approximate coordinates of 3.0°S, 23.5°W. The general area is moderately smooth mare material, exhibiting clusters of craters somewhat eroded in appearance, possibly associated with rays from Copernicus. The character of the surface is quite similar to that previously seen by Surveyor I, Luna 9, and Luna 13.*

LANDING SEQUENCE

An involved sequence of events within the flight control subsystem, possibly initiated by an anomalous coherent radar reflection from the lunar surface during the final seconds before touchdown, caused Surveyor III to initially impact the lunar surface with the vernier engines on. The close balance between the weight of the spacecraft in a 1/6 g field and the minimum thrust level of the vernier engines allowed the spacecraft to rebound. It remained off the surface for 24 seconds before re-impacting the surface a second time. The spacecraft again rebounded, remaining off the surface for an additional 12 seconds prior to its final free fall impact at about 5 fps vertical velocity.

The spacecraft landed with footpad 2 facing uphill. Since it bounced slightly after its final impact, gravity carried the spacecraft slightly downhill during this period. An imprint of footpad 2 is visible about one foot uphill from its rested position (a portion of an imprint is also visible near footpad 3). This fortuitous situation allows us to view a Surveyor footpad imprint in remarkable detail. The waffle

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*Surveyor I and Luna 13 also landed in Oceanus Procellarum. Luna 9 may have landed in either Oceanus Procellarum or nearby highlands.

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pattern associated with the honeycomb structure on the bottom of the footpad is clearly visible, thus indicating that the material is fine grained and capable of retaining the imprint pattern.

Analysis of photographs obtained from panoramic TV surveys has revealed the definite location of the footpad imprints associated with the second impact of the spacecraft. All three footpad locations are discernible as well as the double imprint of footpad 2, predictable by strain gage data. Correlation of a trench-like depression with the surface interaction of vernier engine #3 has also been made. It should be noted, however, that the results of a sudden change in pressure profile (engine shut-off near the surface) and subsequent release of the gas pressure built up in the pores of the soil would not be available. Vacuum chamber tests have indicated that this form of erosion presents the greatest possible hazard to Apollo.

DEPOSIT OF LUNAR MATERIAL ON SPACECRAFT

The area causing the most concern is associated with a glare problem observed early in the mission when photographs were taken in the general direction of the morning sun. Reflection of the sun off the mirror onto the vertically mounted vidicon was observed in Surveyor I; however, the image of the sun was well defined. On Surveyor III a rather well defined glare area was also observed but it seems to be associated with a deposit of foreign material or surface abrasion as well as sun reflection off the mirror. The author feels that the effect is possibly associated with the reflection of exhaust gases off the lunar surface during one of the impacts, when the vernier engines were on. Prior to launch, the mirror was oriented to look at the footpad 3 area and would be susceptible to impingement of exhaust gas or material from the lunar surface.

A few particles of foreign material also appear on the filter wheel assembly. Since the filter wheel is exposed from lift-off, these few particles should not necessarily be taken as lunar surface material.

Narrow angle photographs were taken to determine if any lunar material had been deposited on the footpad during the landing sequence. Examination of the photographs shows that particles indeed have been deposited and they can be related to the vernier engine interaction with the soil since the landing leg structure appears to have shielded the forward portion of the footpad from receiving any material. The footpad is not covered with material, but many distinct particles are clearly visible.

SOIL MECHANICS SURFACE SAMPLER OPERATIONS

The surface sampler operations were of great interest to Apollo. Static bearing tests, dynamic bearing tests, and trenching operations were performed. In addition, soil clods and rocks were moved. The maximum depression obtained by either the static or dynamic bearing tests was less than 2 inches. During static tests, a maximum force of about 8 lbs was applied over a surface of 2 sq. in. Associated with many of the bearing tests is a radiating fracture pattern in the very thin layer of surface material.

Trenching operations were conducted to a maximum depth of about 7 inches. Scrambled telemetry prevented the determination of surface sampler motor current data, which would have provided a quantitative measurement that could have been correlated to surface strength. However, difficulty in being able to retract the mechanism during digging operations indicated that the strength of the material was increasing with depth. Although no layering was observed, the material below the visible surface is consistently darker than the undisturbed material. A static bearing test was conducted at the bottom of one of the four trenches; all that could be initially observed was a slight depression and a smoothing out of the clumpy material. Since the side walls of the trenches were quite stable, the estimate of the minimum value for the cohesion of the lunar soil has increased to about .05 psi. Observations of soil sampler operations have also indicated that the soil is predominantly incompressible.

Three rock-like pieces of lunar material were picked up by the surface sampler. It was confirmed that one was actually a rock since the surface sampler was unable to crush it between the bucket edge and the door when a pressure of from 200-300 psi was applied. One of the pieces was definitely a clod of material, while the other was deposited on the footpad along with other lunar soil and no attempt was made to crush it.

IMPLICATIONS OF SURFACE SAMPLER OPERATIONS ON VERNIER ENGINE EXPERIMENT

Primarily due to early problems with the flight control subsystem and the 14° spacecraft tilt, no erosion experiments were performed.

Prior to the Surveyor III mission, however, it had been planned to fire the vernier engines for 1/2 second. As a result of the surface sampler operations on Surveyor III, indicating that the estimated minimum value of cohesion has increased, it is now felt that a firing of from 5 - 10 seconds would be necessary before a reaction would be noticeable. The material would, in all likelihood, eject in clumps rather than in discrete particles.

Another reason for increasing the firing time is due to the fine grain size of the material. A firing time of 1/2 second would not cause the pressure profile to build up to a depth that would cause a noticeable reaction when the engines are shut off.

CONCLUSIONS

Preliminary analysis of the data returned from the Surveyor III mission has greatly increased the confidence in the ability of the lunar surface to support the LM, as well as the astronauts, in Oceanus Procellarum.

Even though we have learned a great deal about the lunar soil properties from the two successful Surveyor missions, complete confidence does yet exist that all problems associated with the surface interaction of the LM descent engine exhaust can be predicted. As a result, the successful static firing of the vernier engines on future Surveyor missions must remain a primary objective.

Recent work at JPL has resulted in a better understanding of the useful data that can be obtained from an attitude jet experiment. It is also recognized that a static vernier engine experiment poses a higher risk of possible spacecraft destruction than does an attitude jet experiment. It is therefore recommended that both experiments be considered together and that the attitude jet experiment be performed prior to the vernier engine experiment. This would serve a twofold purpose, first to supply data that could possibly allow a better selection of firing time for the vernier engines and, secondly, to allow engineering interrogation of some of the subsystems needed for the vernier engine firing.

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